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ERRATA.

Page 2, sixth line: read equilateral triangle.

Page 2, fourteenth line: for *isoceles*, read equilateral.

Page 8, eighth line from bottom: for *liquidation*, read liquation.

Page 9, ninth line: for *Sn.*, 2.5, read Sn. 0.5.

Page 11, nineteenth line: for 4*t*, read 3*t*; and for 50, read 55.

Page 11, twenty-first line: for 50, read 55.

Page 11, twenty-second line: for 12.5, read 18.

Page 238, fifth line: insert the figures 242, so that it will read (see p. 242).

Page 241, omit lines 17, 18 and 19, and in their place read: WILLIAM R. HUTTON.—The data from which the table on the following page has been prepared have been gathered from various sources.

Page 241, twentieth line: for *flow discharges*, read flood discharges.

Page 242, second line of table: for 84, read 8.4. Third line of table: for 131, read 13.1.

Page 250, first line: for *J. J. R. Cross*, read J. J. R. CROES.

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CCXIV.

(Vol. X.—January, 1881.)

THE STRONGEST OF THE BRONZES.

A NEWLY DISCOVERED ALLOY OF MAXIMUM STRENGTH.

By ROBERT H. THURSTON, Member of the Society.

READ JANUARY 5TH, 1881.

The writer, when conducting a series of investigations of the properties of the copper-tin-zinc alloys, in the Mechanical Laboratory of the Stevens Institute of Technology, by request of a committee of the U. S. Board, organized under an act of Congress secured by a request of the American Society of Civil Engineers, and of gentlemen taking an interest

in that enterprise, was led to devise a method of planning that research* and a system of recording data that has since led to the discovery of alloys of probably the maximum possible strength obtainable by any combination of the elements studied.

This system is briefly the following:

In any triangle, B, C, D, Fig. 1, let fall perpendiculars from the vertices to the opposite sides, as for example, $\overline{CE}$. From any point within the triangle, A, let fall perpendiculars AG, $\overline{AH}$, $\overline{AF}$, and draw $\overline{AB}$, $\overline{AC}$, $\overline{AD}$ to the vertices, thus obtaining three triangles, $\overline{ABD}$, $\overline{ABC}$, $\overline{ACD}$; their sum is equal to the area of the whole figure $\overline{BCD}$.

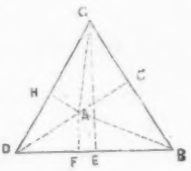


Fig. 1.

Now we have, since the triangle is isoceles, and

$$\frac{\overline{CE} \times \overline{BD}}{2} = \frac{\overline{AF} \times \overline{BD}}{2} + \frac{\overline{AG} \times \overline{BC}}{2} + \frac{\overline{AH} \times \overline{CD}}{2},$$

$$\overline{CE} \times \overline{BD} = (\overline{AF} + \overline{AG} + \overline{AH}) \times \overline{BD};$$

and

$$\overline{CE} = \overline{AF} + \overline{AG} + \overline{AH}$$

which follows wherever the point A may be situated; it is true for every point in the whole area $\overline{BCD}$. Assuming the vertical $\overline{CE}$ to be divided into 100 parts; then $\overline{AF} + \overline{AH} + \overline{AG} = 100$ and $\frac{\overline{AF}}{100}, \frac{\overline{AH}}{100}, \frac{\overline{AG}}{100}$ measures the relation of each of the altitudes of the small triangles to that of the large one.

But we may now conceive the large triangle to represent a triple alloy of which the areas of the small triangles shall each measure the proportion in which one of the constituents enters the compound, and

$$\overline{BCD} = 100 \text{ per cent.} = \left(\frac{\overline{AF}}{100} + \frac{\overline{AG}}{100} + \frac{\overline{AH}}{100}\right) \overline{BD}, \text{ or}$$

$\overline{CE} = 100$ per cent. $= \overline{AF} + \overline{AG} + \overline{AH}$ per cent. and the altitude of each small triangle measures the percentage of some one of the three elements which enter that alloy which is identified by the point. Thus

*On a new method of planning Researches, &c., by R. H. Thurston, Proc. Assoc. for Advancement of Science. Vol. XXVI.

every possible alloy is represented by some one point in the triangle $\overline{B\,C\,D}$, and every point represents and identifies a single alloy, and only that. The vertices *B*, *C*, *D*, in the case to be here considered, represent respectively, copper = 100, tin = 100, zinc = 100. Thus, having determined a method of studying all possible combinations, the writer next prepared to examine this field of work in the most efficient and complete manner possible, with a view to determining, by the study of a limited number of all possible copper-tin-zinc alloys, the properties of all the numberless, the infinite, combinations that might be made, and with the hope of detecting some law of variation of their valuable qualities with variation of composition, and thus ascertaining which were the most valuable for practical purposes.

With this object in view, the triangle laid down to represent this research, was laid off into concentric triangles, Fig. 2, varying in altitude by an equal amount—10 per cent.—on which were laid out the following series of alloys :

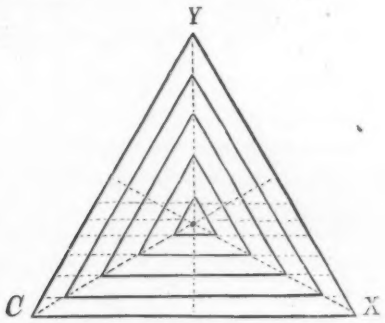


Fig. 2.

COPPER-TIN-ZINC ALLOYS.—THURSTON.

COPPER.	ZINC.	TIN.	COPPER.	ZINC.	TIN.
10	10	80	30	40	30
10	20	70	30	50	20
10	30	60	30	60	10
10	40	50	40	10	50
10	50	40	40	20	40
10	60	30	40	30	30
10	70	20	40	40	20
10	80	10	40	50	10
20	10	70	50	10	40
20	20	60	50	20	30
20	30	50	50	30	20
20	40	40	50	40	10
20	50	30	60	10	30
20	60	20	60	20	20
20	70	10	60	30	10
30	10	60	70	10	20
30	20	50	70	20	10
30	30	40	80	10	10

These alloys were first all tested in the Autographic Recording Machine, and their strain-diagrams were carefully studied. It was at once found that only a very few were of great value, and that the alloys represented by that part of the field lying on the tin-zinc side of a line running from copper = 70, tin = 30, zinc = 0, to the point copper = 40, zinc = 60, tin = 0, were too soft or too brittle and weak to be of value. The research was now restricted to the examination of alloys lying nearer the point copper = 100, *i. e.*, the upper vertex of the triangle as seen in the figure, and all such alloys were tested by tension, compression and torsion, and by transverse stress.

The results were quite accordant, and the quality of the metal could be judged as well by one set of data as by another, although, as a matter of course, the strain-diagram, obtained automatically, gave the best idea of the nature of the metal where the observer had been accustomed to that method. When the figures thus obtained had been entered on the triangular map, lines of equal strength, of equal ductility, or of equal resistance could be drawn, as in topographical work lines of equal altitude are drawn, and the map became thus a useful representation of the valuable qualities of all possible alloys.

Figure 3 represents such a map* of all copper-tin-zinc alloys. The scale of altitudes is obtained by considering the relation of tension to torsion resistance as 25 000 pounds per square inch (1 758 kilograms per square centimeter) for each 100 foot-pounds (13.82 kilogrammeters) of torsional moment for the standard test-specimen, which specimen was turned to a standard gauge, and made $\frac{3}{4}$ inch (1.84 cm.) diameter and 1 inch (2.54 cm.) long in the cylindrical part exposed to strain.

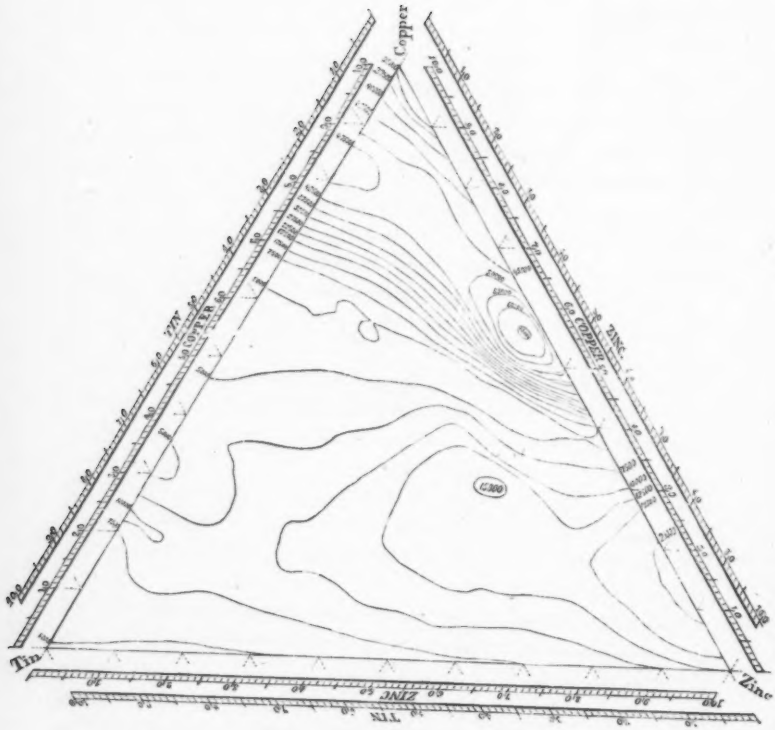
These facts, as determined experimentally, were subsequently still better exhibited by another method devised by the writer for class illustration; thus:

Upon a triangular metal base, laid off as above, erect a light metallic staff by drilling a hole for its support at each point laid down as representative of an alloy tested; make the altitude of each of these wires proportional to the strength of that alloy. There is thus produced a forest of wires, the tops of which are at elevations above the base-plane proportional to the strengths of the alloys studied. Similar constructions may be made to represent the elasticity, the ductility, or any other property of all these alloys.

Next fill in between these verticals with clay or, better, with plaster, and carefully mould it until the tops of all the wires are just visible, shining points in the now smooth surface of the model. The surface thus formed will have a topography characteristic of the alloys examined, and its undulations will represent the characteristic variations of quality with changing proportions of the three constituents.

This was made for the writer, and was cast in an alloy which is the subject of this paper, the plaster cast made as above being used as a pattern, and this cast is used in lecture-room illustration, and is supplied where demanded to other institutions.

* Reports of U. S. Board testing Iron, Steel, &c. Washington. 1878—1881.


Copper
Tin
Zinc
TIN
ZINC
COPPER
ZINC
TIN
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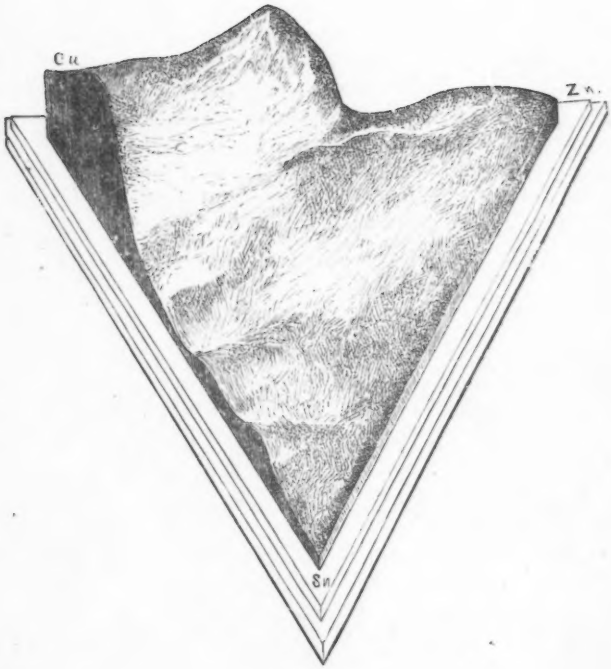

Fig. 4.

Figure 4 is a good representation made from a photograph of the model for the American Association for the Advancement of Science.*

The remarkable variations of quality here so strikingly shown, naturally attracted the attention of the writer, as of every one to whom he exhibited these models and maps, and a further investigation was made.

The alloys studied were originally intended to furnish data during a preliminary research that should serve as a guide in a later and more complete study of this important and intensely interesting field of investigation; the plan was never completely carried out, in consequence of

* Proceedings, 1878, Vol. XXVI.

the failure of Congress to make needed appropriations and the consequent demise of the Board.* These alloys were purposely made precisely as the brass-founder is accustomed to make them, without other precautions than those observed by every good founder, and without using any of the deoxidizing fluxes—as phosphorus—that would have been experimented with later. The intention was to make this first survey of the field rapidly, inexpensively, and in such a manner as to give a good idea of the best way to pursue the later and much more exact research, while giving the founder a good idea of the nature of the metals that he turns out in every day work.

The data obtained were consequently exceedingly variable, and the results of this work indicated as one, and not the least valuable, of deductions from it that the same alloy, and especially where the proportion of copper is great, may give very different figures when tested according as it is more or less affected by the many circumstances that influence the value of all brass-foundry products.

Some of the variations in the model are probably due to such accidental circumstances, and quality shown by any individual alloy is representative of a mean which the writer was often compelled to deduce from observations which were quite discrepant. But allowing for all such minor variations, it is evident at a glance that the alloys of maximum strength are grouped, as shown in Figures 3 and 4, about a point not far from copper = 55, zinc = 43, tin = 2. This point is encircled in the map, Figure 3, by the line marked 65 000 pounds per square inch (4 570 kilogs. per sq. cm.) tenacity, and is represented on the model, Figure 4, by the peak of the mountain seen at the farthest side—the copper-zinc side as drawn.

This is obviously the strongest of all bronzes, and an alloy of this composition, if exactly proportioned, well melted, perfectly fluxed, and so poured as to produce sound and pure metallic alloy, with such prompt cooling as shall prevent liquidation, is the strongest bronze that man can make.

The writer finally made this alloy, and of it constructed the model represented in the last figure. It is a close-grained alloy of rich color, fine surface, and takes a good polish. It oxidizes with difficulty, and the surface then takes on a pleasant shade of statuary bronze green.

* An effort which has been recently made to re-establish the Board has not yet (December, 1880.) met with success.

Testing it, it was found to have considerable hardness, but moderate ductility, though tough and ductile enough for most purposes; it would forge if handled skillfully and carefully and not too long or too highly heated, had immense strength, and seemed unusually well adapted for general use as a working quality of bronze. In composition, however, it is seen to be a brass, with a small dose of tin.

The alloy made as representing the best alloy for purposes demanding toughness as well as strength contains less tin than the above composition. Cu., 55; Sn., 2.5; Zn., 44.5.

It had a tenacity of 68 900 pounds per square inch (4 841 kilogs. per sq. cm.) of original section, and 92 136 pounds (6 477 kilogs.) on fractured area, and elongated 47 to 51 per cent., with a reduction to from 0.69 to 0.73 of its original diameter.

No exaltation of the normal elastic limit was observable during tests made for the purpose of measuring it if noted. This alloy was wonderfully homogeneous, two tests by tension giving exactly the same figure 68 900. The fractured surface was in color pinkish yellow, and was dotted with minute crystals of alloy produced by cooling too slowly. The shavings produced by the turning tool were curled closely, like those of good iron, and were tough and strong.

The strain-diagrams from the autographic machine are shown in *fac simile* and of full size in the accompanying Plate 1. Their tenacity, as estimated from their resistance to torsion, is nearly equal to that determined by direct experiment, and the four samples tested 1 001 *A*, *B*, *C*, *D*, have given strain-diagrams that are all nearly precisely alike. They exhibit an elastic limit, *e*, at about $\frac{2}{3}$ their ultimate resistance, and just about the same as a piece of excellent gun bronze (Cu.90; Sn. 10 per cent.), 1 252 *A*, the strain-diagram of which lies beside them in dotted line. Their elastic resistance, which is measured by the area of the curve up to *e*, is superior to that of the gun bronze, and their elastic range is seen to be greater on inspection of the "elasticity lines," *e' e'*. In ductility they excel 1 252 *A*, but not greatly, as is seen by comparing 1 001 *A* with 1 252 *A*. Their toughness is shown by the great area and the altitude of the curve; their excellence of quality is also shown by its smoothness of outline. The homogeneousness of structure is exhibited by the similarity of the diagrams and by the smoothness of the bend at *e*, which marks the elastic limit.

At f is a depression of the normal line of elastic limits produced by 17 hours intermission of distortion under the load there carried. This slight depression marks this alloy as one of the "tin class."

Diagram 1252 B is given by a very fine gun bronze; 1001 x is an hypothetical diagram, such as would be produced were the alloy here described so carefully fluxed and cast as to exceed in strength the unfluxed alloys actually tested, 1001 A, B, C, D in as great a proportion as 1252 B excels 1252 A. The diagram 1001 y would be produced were it possible to so far improve this alloy as to cause it to excel 1252 A as greatly as No. 1001 actually did excel the gun bronze made under similar conditions in this preliminary rough work. No. 1004 A is copied to exhibit the immense superiority of the alloy 1001 to one but little removed from it and which is considered by some brass founders an excellent composition.

It is impossible to say, without direct test, to what extent the alloys shown in figures 3 and 4 may be improved by special methods of working, and by more perfect fluxing than is usually secured in the foundry. This was to have been the subject of the next investigation; the ground had been cleared and the valuable alloys identified, and the work planned could have been rapidly and satisfactorily done had the opportunity been allowed. But from what can be gathered by the experience acquired the writer is inclined to suppose that careful mixture, thorough fluxing with phosphorus or other deoxidizing element, casting under pressure, rapidly cooling, and finally cold-rolling or cold pressing as practised by Dean,* copper-tin-zinc alloys, containing not to exceed $z+3t=30$ per cent. could be given a strength exceeding by 50 per cent. that obtainable under the ordinary conditions met with in the brass foundry. During the writer's experiments the copper used had a tenacity, as cast in small bars, of but one-half that obtained by Mallett, who fluxed out the oxygen more completely. Similarly, in these preliminary trials, gun bronze broke at two-thirds the figure obtained frequently in making ordnance.

Alloys rich in copper receive most benefit by such special treatment.

The writer has found that ordinary bronze, composed of copper and tin, may be taken with rough approximation to accuracy as having a tenacity, as cast in the ordinary course of a brass founder's business, of

* On the Mechanical Treatment of Metals; by R. H. Thurston; Metallurgical Review. 1877.

about—

$$T_t = 30\,000 + 1\,000\,t;$$

where t is the percentage of tin, and not above 15 per cent. Thus gun bronze can be given about $30\,000 + (1\,000 \times 10) = 40\,000$ pounds per square inch, if well made. In metric measures

$$T_t^1 = 2\,109 + 70.3\,t,$$

giving for good gun-metal $2\,109 \times 703 = 2\,812$ kgs. per sq. cm.

For brass (copper and zinc) the tenacity may be taken as

$$T_z = 30\,000 + 500\,Z;$$

where the zinc is not above 50 per cent.; and

$$T_z^1 = 2\,109 + 35.15\,Z.$$

Thus copper 70, zinc 30, should have a strength of $30\,000 + (500 \times 30) = 45\,000$ pounds per square inch, or $2\,109 + (35.15 \times 30) = 3\,165$ kilogrames per square centimeter.

Referring once more to figures 3 and 4, it is seen that a line of maximum elevation crosses the field marking the crest of the mountain in Figure 4, of which the "maximum bronze" is the peak. This line of valuable alloys may be practically covered by the formula:

$$M = z + 4\,t = \text{Constant} = 50,$$

in which z is the percentage of zinc, and t that of tin. Thus a maximum is found at about $t = 0$, $z = 50$, while the other end of the line is $z = 0$, $t = 12.5$.

Along this line the strength of any alloy should be at least

$$T_m = 40\,000 + 500\,z.$$
$$T_m^1 = 2\,812 + 35.15\,z.$$

Thus the alloy $z = 1$, $t = 18$ will also contain copper $= 100 - 19 = 81$ and this alloy cu. 81, zn. 1, sn. 18 should have a tenacity of at least

$$T_m = 40\,000 + (500 \times 1) = 40\,500 \text{ lbs. per sq. in.}$$
$$T_m^1 = 2\,812 + (35.15 \times 1) = 2\,847 \text{ kgs. per sq. cm.}$$

The alloy: cu. 60; zn. 5; sn. 16; should have at least the strength

$$T_m = 40\,000 + (500 \times 5) = 42\,500 \text{ lbs. per sq. in.}$$
$$T'_m = 2\,812 + (35.15 \times 5) = 2\,988 \text{ kgs. per sq. cm.}$$

while the alloy *z*, 50; sn, 2; cn, 48; should give, as a minimum per specification:

$$T_m = 40\,000 + (500 \times 50) = 65\,000 \text{ lbs. per sq. in.}$$
$$T'_m = 2\,812 + (35.15 \times 50) = 4\,570 \text{ kgs. per sq. cm.}$$

These are rough working formulas that, while often departed from in fact, and while purely empirical, may prove of real value in framing specifications. The formula for the value of T_m fails with alloys containing less than 1 *per cent. tin* as the strength then rapidly falls to $t = 0$.

The improvement that may be expected to follow special treatment of some, and probably nearly all the more valuable of these alloys, may be inferred from the fact that Mr. S. B. Dean, in 1869,* increased the tenacity of cast gun-bronze from 27 230 to 41 471 pounds per square inch (1 915 to 2 915 kilogs. per sq. cm.) by cold-working, and General Uchatius, who introduced the Dean process in Austria, by chilling, increased the strength of his "steel-bronze" from 35 092 pounds per square inch (2 260 kilogs. per sq. cm.), to 43 310 pounds (3 050 kilogs.);† the elastic limit remaining, however unchanged at 5 680 pounds per square inch (400 kgs. per sq. cm). This metal then cold-rolled by the Lauth method of Jones & Laughlin's, rose in tenacity to 71 937 lbs. with an elastic limit at 24 140 (5 066 and 1 700 kilogs. per sq. centimetre). This was the regulation alloy: copper, 90; tin, 10. When the tin was increased to 12 per cent. the alloy was too hard to roll.

Colonel Rosset, of the Italian army, repeated Dean's work and extended it with the same result.‡

On the copper side of the maximum point on our map and model of

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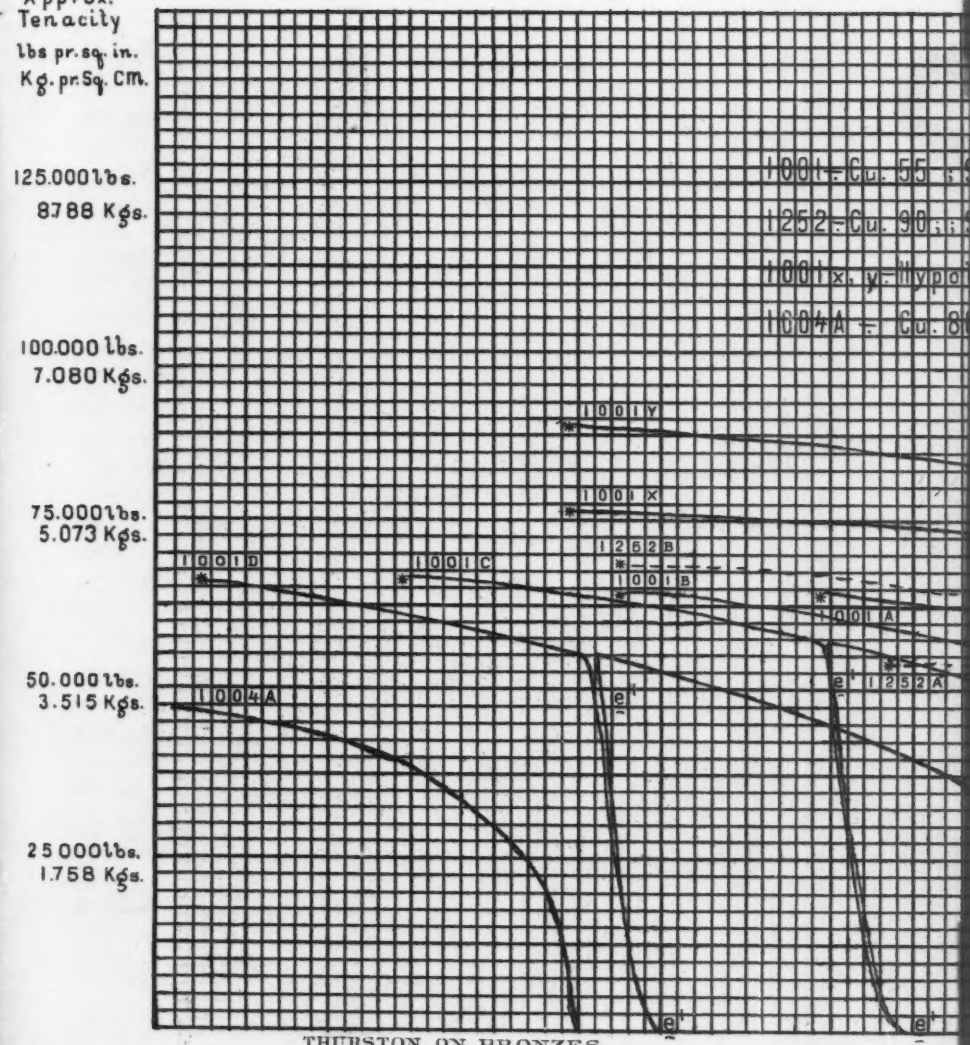
* Ordnance Notes, No. XL, p. 255.

† Report on Manufactures and Machinery at Vienna, 1873; R. H. Thurston: p. 326.

‡ Resistenza dei Principali Metalli; Torino; 1874.



THURSTON ON BRONZES.

FAC-SIMILE AUTOGRAPHIC STRAIN DIAGRAM.

1001=Cu. 55 ; Sn. 05; Zn. 445

1252=Cu. 90 ;; Sn. 10.

1001x, y=Hypothetical Diagrams

1004A = Cu. 80; Sn. 125; Zn 75

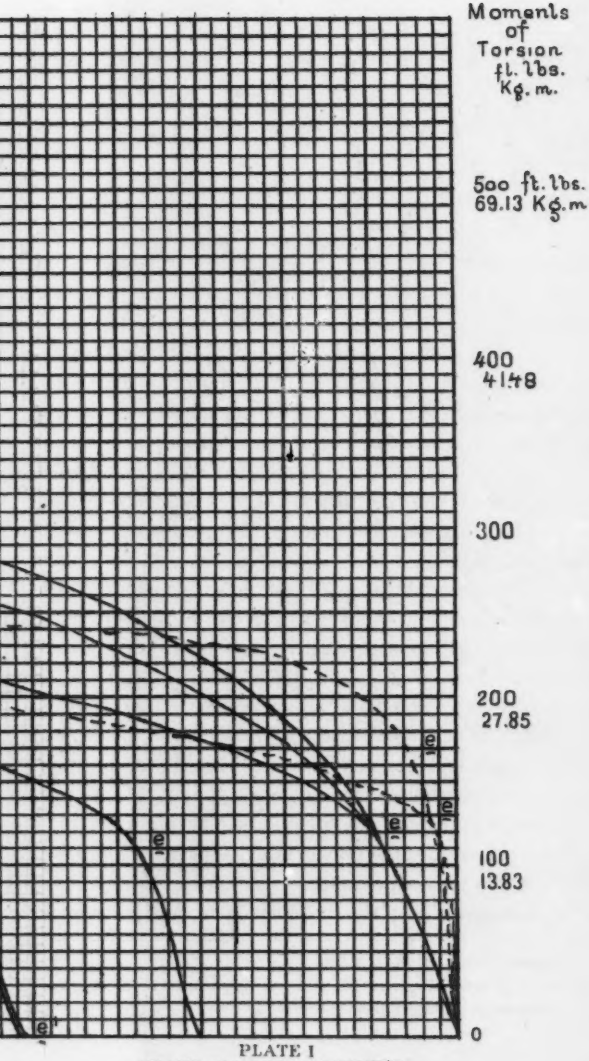


PLATE I
TRANS. AM. SOC. CIV. ENGR'S
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the copper-tin-zinc alloys, is one that has been well studied and is of remarkable value. This metal was discovered by Mr. J. A. Tobin (U. S. Naval Engineer Corps), and described to the writer several years ago. § It consists of copper, 58.22; tin, 2.30; zinc, 39.48; it is hardly as strong as the alloy already described, but as cast had a tenacity of 66 500 pounds per square inch of original section, and 71 378 per square inch of fractured area (4 575 and 5 019 kilograms per sq. cm.) at one end of the bar which was, as usual, cast on end, and 2 per cent. more at the other. This alloy, like the maximum metal, was capable of being forged or rolled at a low red heat or worked cold. Rolled hot its tenacity rose to 79 000 pounds (5 553 kgs. pr. sq. cm.), and when moderately and carefully cold-rolled, to 104 000 pounds (7 311 kgs.). It could be bent double either hot or cold, and was found to make excellent bolts and nuts.

A large proportion of the alloys on the copper side of the crest marking the line $z + 4t = 50$ may be treated with equal or greater success, and there should be no trouble in securing copper-tin-zinc alloys of tenacities between 75 000 and 100 000 pounds per square inch (5 273 to 7 030 kilogs. per sq. cm.), by intelligent and skillful working. As I have elsewhere stated, ‖ the metals used should be perfectly pure (Lake Superior copper; Banca or Australia tin; and New Jersey zinc); they should be protected from oxidation when fusing, carefully fluxed with phosphorus or other good deoxidizer, poured quickly into chills, cooled with the utmost rapidity, and the castings, when possible and safe so to work, rolled or forged either cold or hot. Should the work of the U. S. Board to Test Metals ever be resumed, this is likely to prove one of the most important and profitable lines of investigation. The results here given, it is obvious, are subject to revision after more work has been done, and the revision of data already obtained, the exclusion of unreliable and valuable observations, and the formulation of more precise deductions will furnish employment for future investigators.

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§ By letter dated Feb. 6th, 1876, and verbally in 1875.

‖ Metallurgical Review, 1877; Mechanical Treatment of Metals.

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INSTITUTED 1852.

TRANSACTIONS.

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CCXV.

(Vol. X.—January, 1881.)

RENEWAL OF THE FOUNDATION, AND TRANSFER OF A LIGHT-HOUSE IN PASCAGOULA HARBOR.

By J. W. PUTNAM, Associate A. S. C. E.

READ DECEMBER 1, 1880.

The coast of the Gulf States is a low, sandy foundation, presenting no bold, abrupt headlands, and very few points where a depth of water sufficient for small schooners can be found near the coast line. The bottom is a long, gradual slope extending for several miles seaward. The outlying islands are loose banks of sand continually changing in contour by the force of storms from different points of the compass.

The Government finds it necessary to maintain lights on the islands

near the channels, and to mark the channels by buoys. A great difficulty in maintaining light-houses arises from the shifting character of the islands. It is difficult to excavate to any great depth, as the water washes in, bringing with it the loose sand.

Screw pile foundations were adopted some years since by the Light-House Department, but the piles cannot be driven to a depth below where they are liable to be washed out in a single storm. Some islands have been cut in two, and channels formed through, while others have entirely disappeared.

The channel entrance to Pascagoula harbor and river (Plate II.), is between the east end of Horn Island and the west end of Petit Bois Island. The light is on Horn Island, and was built a few years ago near the centre of the island, north and south, on screw piles. Gradually the island has been disappearing, and the sea approaching, while the point of Petit Bois, across the channel, has been extending. Brush mattresses were placed along the front, and secured by piles to protect the light-house, but were about as effective as the commands of King Canute. To resist the strength of the waves, they were about like spider webs in the path of a locomotive.

The erosion progressed until the sea stood there four, five, six feet deep, under one side of the light-house, excavating and filling according to the direction of the wind, but always carrying out more than was brought back. A removal of the light-house was found to be its only salvation, but its removal a mile to the westward would necessitate a change in the charts.

Not desiring to make such extended and expensive changes, Capt. W. H. Heuer, (Corps of Engineers, Member A. S. C. E.) light-house engineer, in charge of the district, turned his attention towards creosoted piles, with which a foundation could be made, reaching to a depth below the deepest water of the harbor or pass, and through which the storms could drive without injury.

Borings made on the island revealed the fact (Plate II.), that it was a bank of loose sand, and worn and broken shells, to a depth of about twenty feet. Below that was an old and submerged grass marsh, from which pieces of sod were brought up, containing all the little roots and fibers of the ordinary marsh sod. It had evidently been formed at or above the surface of the water, and plainly indicates the subsidence of the continent.

Below this marshy, vegetable deposit of about twenty feet, was found a hard, sandy stratum, making a firm and solid bearing for the piles. Yellow pine piles, seventy-five feet long, were procured and thoroughly creosoted at the creosote works of the New Orleans and Mobile Railroad.

As the piles were to be driven as near the old site as practicable, and in barely water enough to float a pile-driver—no pile-driver could be had with leaders (or gins) tall enough to swing its hammer over the top of a seventy-five feet pile. One was procured from the railroad company having leaders over sixty feet high, and carrying a five thousand pound hammer; the leaders being adjusted by machinery, so as to drive a pile at any desired angle. With a powerful force pump the piles were washed down until the hammer would pass over the top, and from there they were driven to a depth of fifty feet below the water line.

The nature of the work, and fluctuations of the tide, rendered progress slow and tedious, less than one pile a day being driven.

Three piles were driven at each corner of the house, and one in the centre to support the lamp. One pile at each corner was driven vertically, and the other two obliquely, spreading from each face of the house at an angle from the vertical of about one in four. The three were then faced and brought together and secured by heavy bolts, making a firm and steady foundation. At the top of the vertical pile is framed a tenon six inches in diameter by eighteen inches long, which enters the iron socket formerly occupied by the iron pile, and the flattened ends of the oblique piles press against the sides of the iron socket (see Plate III.).

The light-house was transferred from the old to the new foundation over a trestle twenty feet high, and with such care that its delicate revolving machinery performed its accustomed work at night, never failing to flash a welcome to the mariner. The keeper, Capt. Freeman, says that it never stood as steady as at present.

It is, I think, the only light-house foundation of its kind in existence. It offers a solution to the question: What can be done to render secure and permanent the sand-bar lights? It is comparatively cheap, and if as indestructible by decay and the teredo navalis, as all appearances indicate, will outlast iron piles.

When the New Orleans and Mobile Railroad built their creosoted bridges, a few piles were driven alongside to be removed for examination from time to time. The Superintendent having decided a few weeks ago

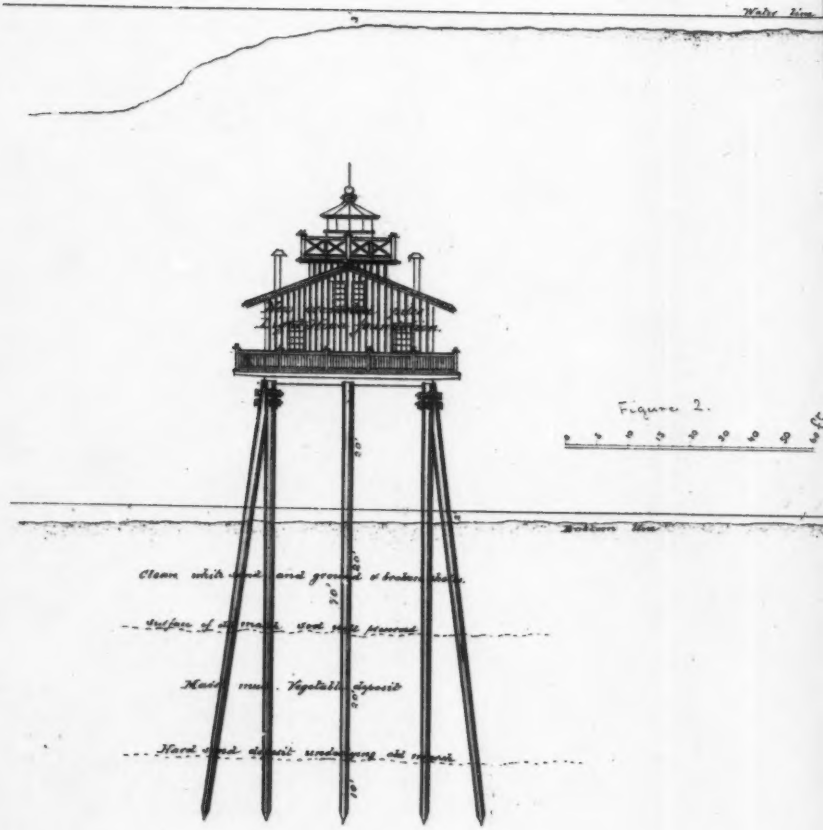
Water line
Bottom line
Clean white sand and gravel & broken shells
Surface of the marsh, peat with grasses
Hard sand deposit underlying old marsh
20'
20'
10'

Figure 2.

SECTION OF HORN ISLAND AT THE LIGHT-HOUSE

showing the old iron screw foundation and the new excavated piles foundation of the Light-house.

Water Line.

Horizontal Scale
Vertical "

Scale

HORN ISLAND

Water Line

Channel bank

Present Light House

and

Scale

HORN ISLAND

HORN ISLAND PASS

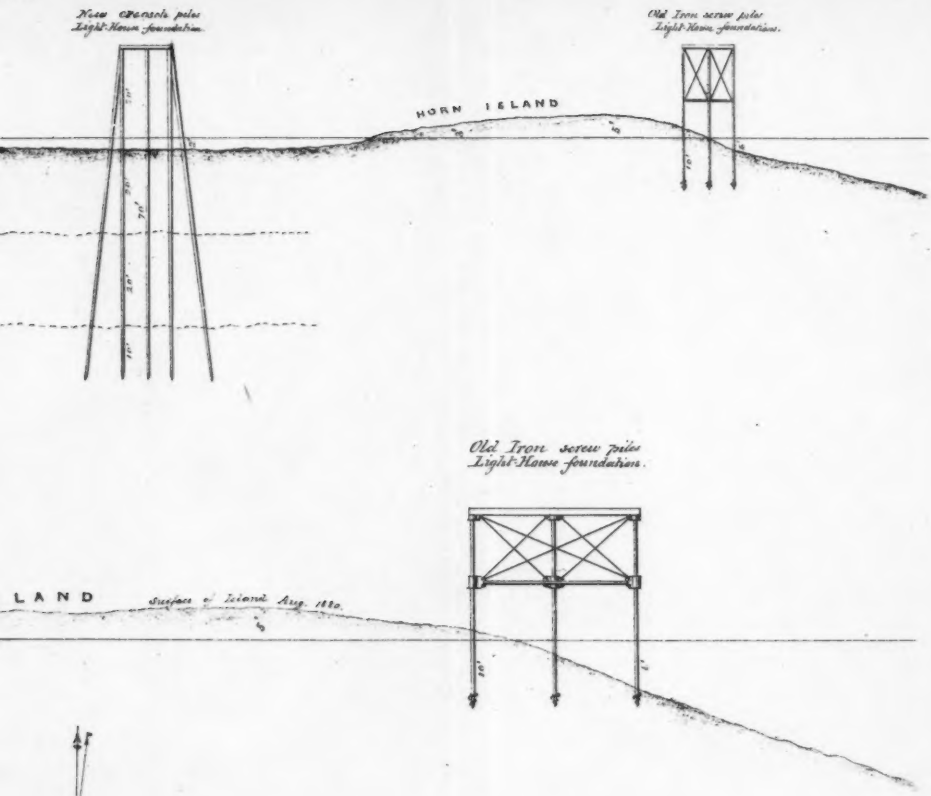
New Screw pile Light House foundation
Old Iron screw pile Light House foundations.
HORN ISLAND
Old Iron screw piles Light House foundations.
LAND
Surface of Island Aug. 1880.

PLATE II.
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to make one of these examinations, invited several gentlemen, among them some officers of the United States Engineers, to be present.

Two piles were taken out, one of which was driven in the autumn (December, I think) of 1872, and the other in June, 1876. They were beside different bridges, but where piles have been frequently cut off by the ship-worm in one year. Both piles were perfectly free from any marks of the teredo.

I have to-day made examinations of one of our oldest creosoted bridges, and find both piles and superstructure in the most perfect condition, though, had the timber not been creosoted, some of it would have been so far decayed as to require renewal.

During the discussion of this paper, questions were asked by several members of the Society, and have been answered by the author as follows:

What did the work cost?

J. W. PUTNAM.—Three thousand dollars; this included the cost of the 13 creosoted piles, 75 feet long, towing the pile driver to Horn Island and back, driving the piles, building camp, building a trestle over which to move the house, the timber and lumber required for blocking and stagings, and all labor from first to last; the trestle was thirty feet wide, and strong, and braced to stand any probable storm; the house weighs about fifty tons, I think, from the indications while handling it. The bents of trestle were fifteen feet, from centre to centre, resting on a floor of short plank, five feet wide underneath the sills; the stringers were thirteen inches by sixteen inches, and the timbers placed underneath the sills of the house, of the same size, thirty-five feet long; rollers were placed between the timbers and stringers; the stringers bent so that the rollers near the bents carried the greater part of the load; we found it necessary to use fifteen rollers on each side; to move the house required a heavy pair of double blocks and a pair of smaller blocks for a luff on each side, and a double six inch line to a winch on the pile driver.

Why not lower the pile the whole distance by the water process?

J. W. PUTNAM.—About twenty feet of the upper part of the island is loose, white sand, and ground and broken shells; it washes very easily, having no bond but gravity to hold it in place; before the pile could be lowered, so as to swing under the hammer, the sides of the excavation

would cave in around the pile and stop its descent, the water from the pump being diffused through the loose sand; the pile then had to be raised and lowered again, with, perhaps, the same result; in this way it often required fifteen or twenty trials to get the pile under the hammer; we used the pump to loosen the sand, while driving, at first, but found it of little value.

What were the details of the method of getting the piles down by the water process?

J. W. PUTNAM.—After the pile had been raised by the pile driver, a two inch gas pipe, forty feet long, was placed beside it, the lower end passing through a staple driven near the point of the pile; the upper end was lashed to the pile; a hose leading from the pump was connected to the pipe by a union; the pump was then set in motion, and the pile lowered as the sand was washed away.

What is the level of the top of piles above water?

J. W. PUTNAM.—Twenty feet.

What is the present depth of water?

J. W. PUTNAM.—From one and one-half to two feet.

What distance was the light-house moved?

J. W. PUTNAM.—About three hundred feet; I do not recollect the exact distance.

What will be the probable security of this light-house, standing on five supports only, in case the sand shall be washed to a considerable depth, as the paper of Mr. Putnam seems to indicate as possible or probable.

J. W. PUTNAM.—Though the light-house is supported at only five points, the three piles at each corner so diverge as actually to constitute thirteen points of support at the bottom; the house is about thirty feet square, and the spread of the piles gives it a base of sixty-five or seventy feet square. They are so bolted together at the top as to resist a storm that would destroy the house. I have driven them for bridge foundations in water forty and fifty feet deep, the end piles of each pier being driven obliquely, in a similar manner, and with the current running faster than the Mississippi river ever runs at New Orleans, and estimated at ten miles per hour. There was no perceptible variation in the alignment of the ack. This result cannot possibly be obtained if the piles are driven vertically, and sprung for bracing in the usual way. I therefore think that if the whole island should wash away, to a depth of thirty or

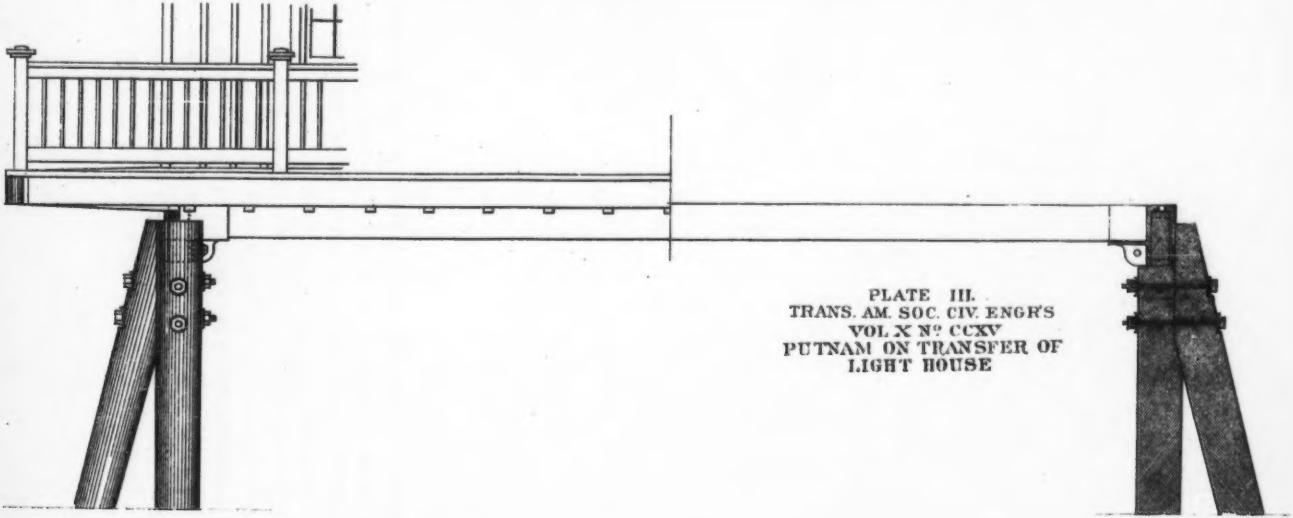

PLATE III.
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forty feet, the light-house would be perfectly safe, *i. e.*, as far as its foundation is concerned. I think it altogether probable that within the next few years the whole eastern end of Horn Island will disappear, and that the whole outlying chain of islands, that divides the Gulf from Mississippi Sound will follow suit. Perhaps the sand may drift around and pile up in dams, so as to keep a picket line for the continent. Of this I feel assured, that the old coast line was far outside the line now occupied by those islands, perhaps along the border of the great plateau, extending to six or seven hundred feet in depth of water; that we are gradually subsiding, and that the sea is backing up the Mississippi river.

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TRANSACTIONS.

NOTE—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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DISCUSSION ON PAPER CCX.

WEB STRAINS IN SIMPLE TRUSSES WITH PARALLEL OR INCLINED BOOMS.

By SQUIRE WHIPPLE, Honorary Member of the Society.

PRESENTED FEBRUARY 2, 1881.

Mr. E. Sweet, Jr., Member A. S. C. E., in a paper on "Web Strains in Simple Trusses" (Trans. A. S. C. E., Nov., 1880), takes occasion to criticise the method of calculating such strains upon the assumption that the maximum stress upon any diagonal is equal to that produced by a concentrated panel-load upon each floor beam from one end of the bridge, up to, but not beyond, the panel containing the diagonal in question. This method is objected to by Mr. Sweet as faulty, inasmuch as, in practice, the panel-loads are not so concentrated upon the beams, but may be, and usually are, distributed over the spaces between beams, so

that the maximum weight does not act upon the beam until the load has progressed partly or wholly across the panel containing the diagonal, and bears in part upon the succeeding beam, thereby counteracting in some degree the stress upon the diagonal, which the assumed concentrated loads upon the preceding beams would produce.

Now, believing myself to have been the first to practice and promulgate the method of calculation thus criticised, if it be seriously faulty, I owe an apology to those, if any, who have been led astray thereby, as well as thanks for being set right in the matter. Wishing, therefore, to do what is just, and to put myself right, if I have been in the wrong, I am induced to offer a few remarks.

In all applications of mathematical calculation to practical affairs, we are usually obliged to assume as facts, conditions which are only approximately so; and in matters involving consequences as serious as those liable to result from the failure of a bridge, it is, of course, proper to assume conditions covering extreme contingencies. Now, although the maximum load of a bridge beam *usually* depends upon weight distributed more or less upon adjacent panel-lengths on either side of the beam, this is not a matter of absolute necessity. It is an easily supposable case, that a load may rest upon vehicles with wheels located at distances asunder, corresponding with the distances from beam to beam in the bridge, and each pair of wheels carrying a maximum panel-load for the bridge, in which case the beam would bear its maximum load, and the tension diagonal running upward and forward from the last loaded beam, its greatest stress, when a pair of wheels were directly over such beam, and no load upon the next beam in advance.

Such are the extreme possible conditions which the adopted method of calculation was intended to cover.

On the other hand, a load might be conceived to advance upon a bridge (though I can hardly imagine how) in such manner that each linear foot and inch should bear a uniform weight up to the front line of the advancing load, in which case, each beam would only sustain its maximum load when each adjacent panel-length was loaded throughout.

Now, neither of these supposed conditions as to the load upon a bridge, as I believe, can be shown ever to have actually occurred in practice. Neither is it easy to determine which is the more nearly, or the more frequently approximated to; every actual case possessing more or less of the distinctive features of both.

Mr. Sweet seems to have adopted the latter "assumption," while the writer, and it is believed most other practitioners have made use of the former, with satisfactory results.

The results, however, obtained by the two methods differ not largely, and, while the old method covers the extreme contingency, the proposed substitute, giving usually smaller, but never larger strains, does not as certainly cover *extreme* cases, or such as may actually occur.

I have not followed out all the details of Mr. Sweet's elaborate formulations, but consider it presumable that he has deduced legitimate results from his premises. It was hardly to be expected, however, that after entering his protest against a method of calculation based, as he alleges, upon an illegitimate "assumption" of facts and conditions, he would proceed to elaborate a method as a substitute resting upon an *assumption* which can scarcely be claimed to be more consistent with the actual conditions occurring in practice.